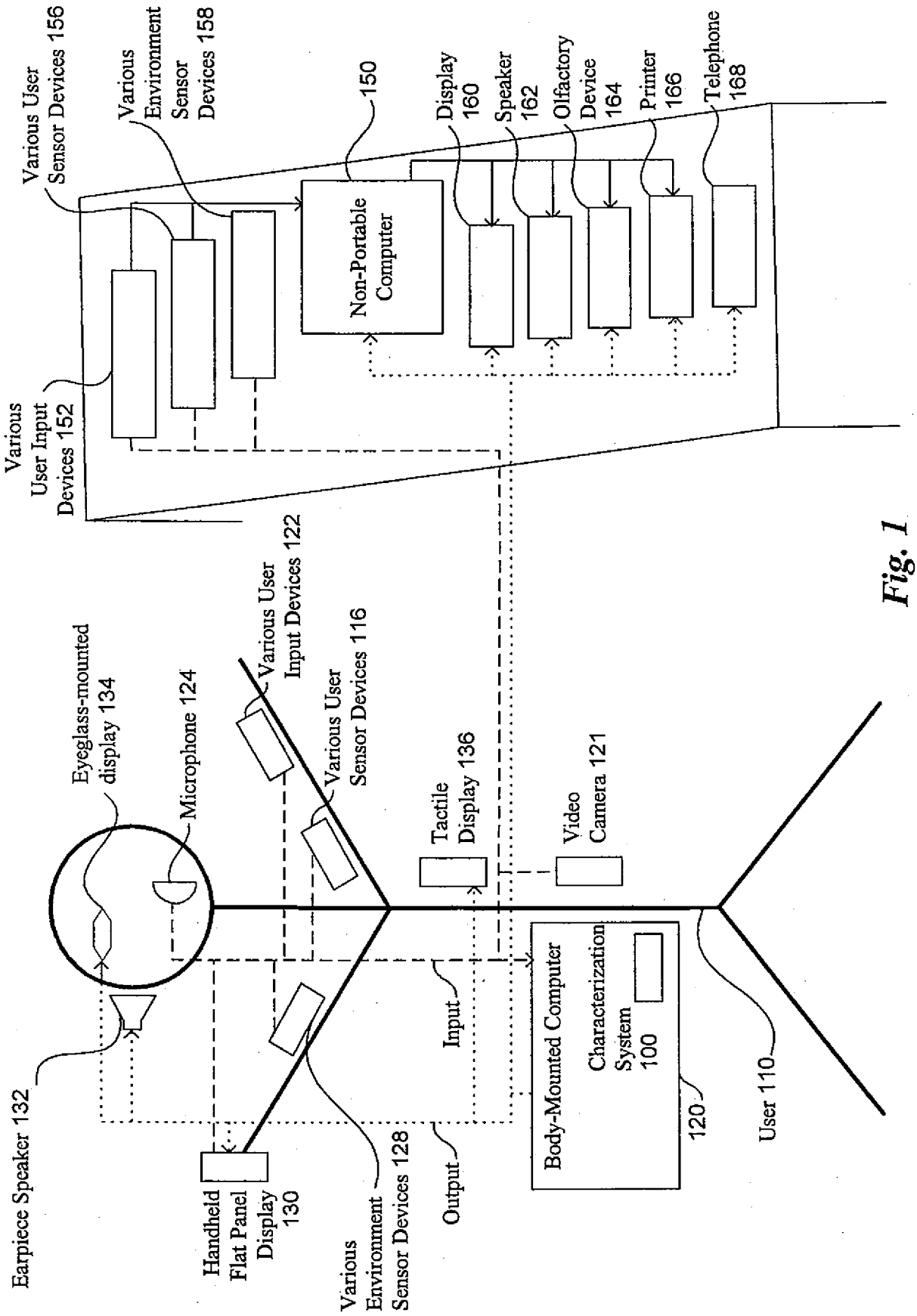

Various User Sensor Devices 156
Various Environment Sensor Devices 158
150
Display 160
Speaker 162
Olfactory Device 164
Printer 166
Telephone 168
Non-Portable Computer
Various User Input Devices 152
Various User Input Devices 122
Various User Sensor Devices 116
Eyeglass-mounted display 134
Microphone 124
Tactile Display 136
Video Camera 121
Earpiece Speaker 132
Handheld Flat Panel Display 130
Various Environment Sensor Devices 128
Input
Output
Body-Mounted Computer
Characterization System 100
120
User 110

Fig. 1

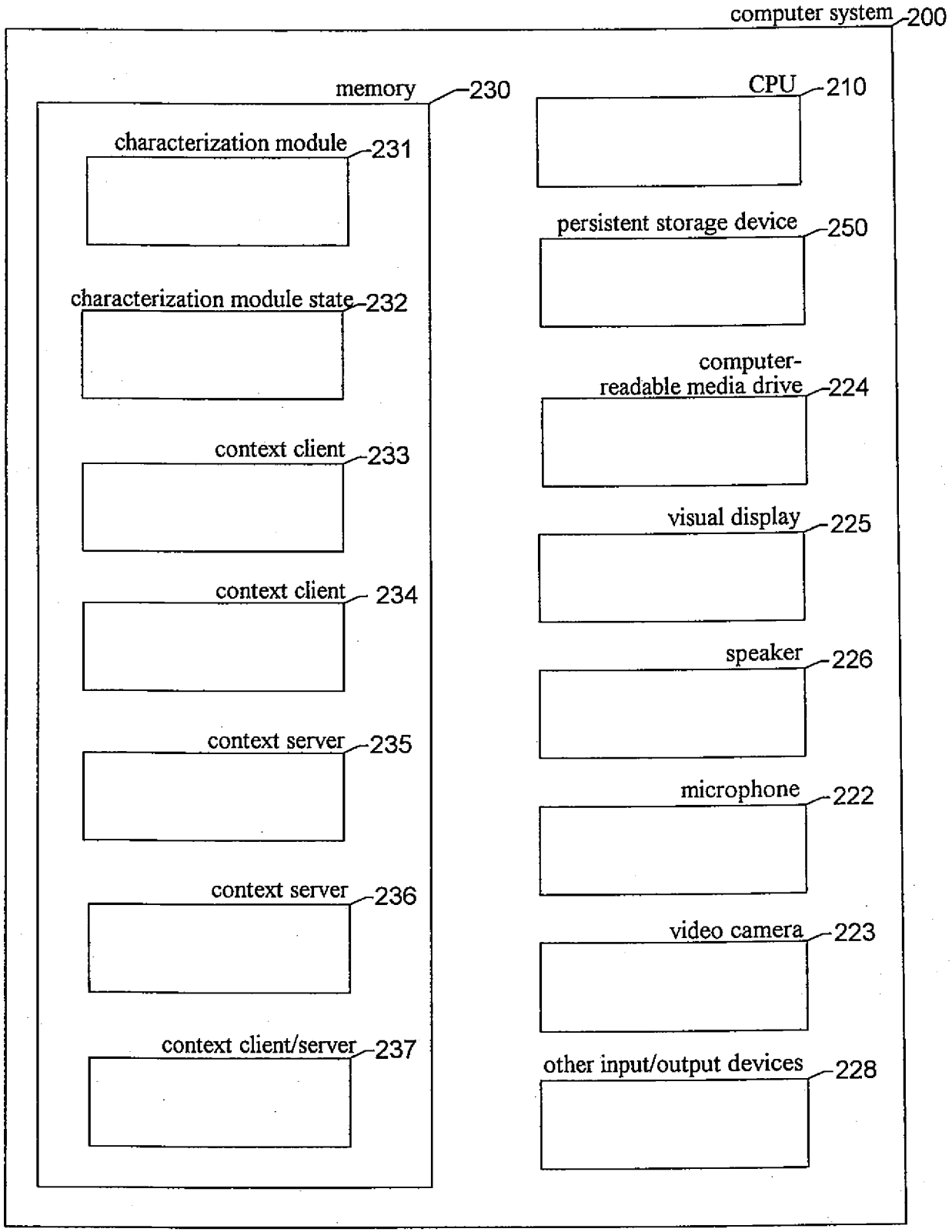

computer system 200
memory 230
characterization module 231
characterization module state 232
context client 233
context client 234
context server 235
context server 236
context client/server 237
CPU 210
persistent storage device 250
computer-readable media drive 224
visual display 225
speaker 226
microphone 222
video camera 223
other input/output devices 228

Fig. 2

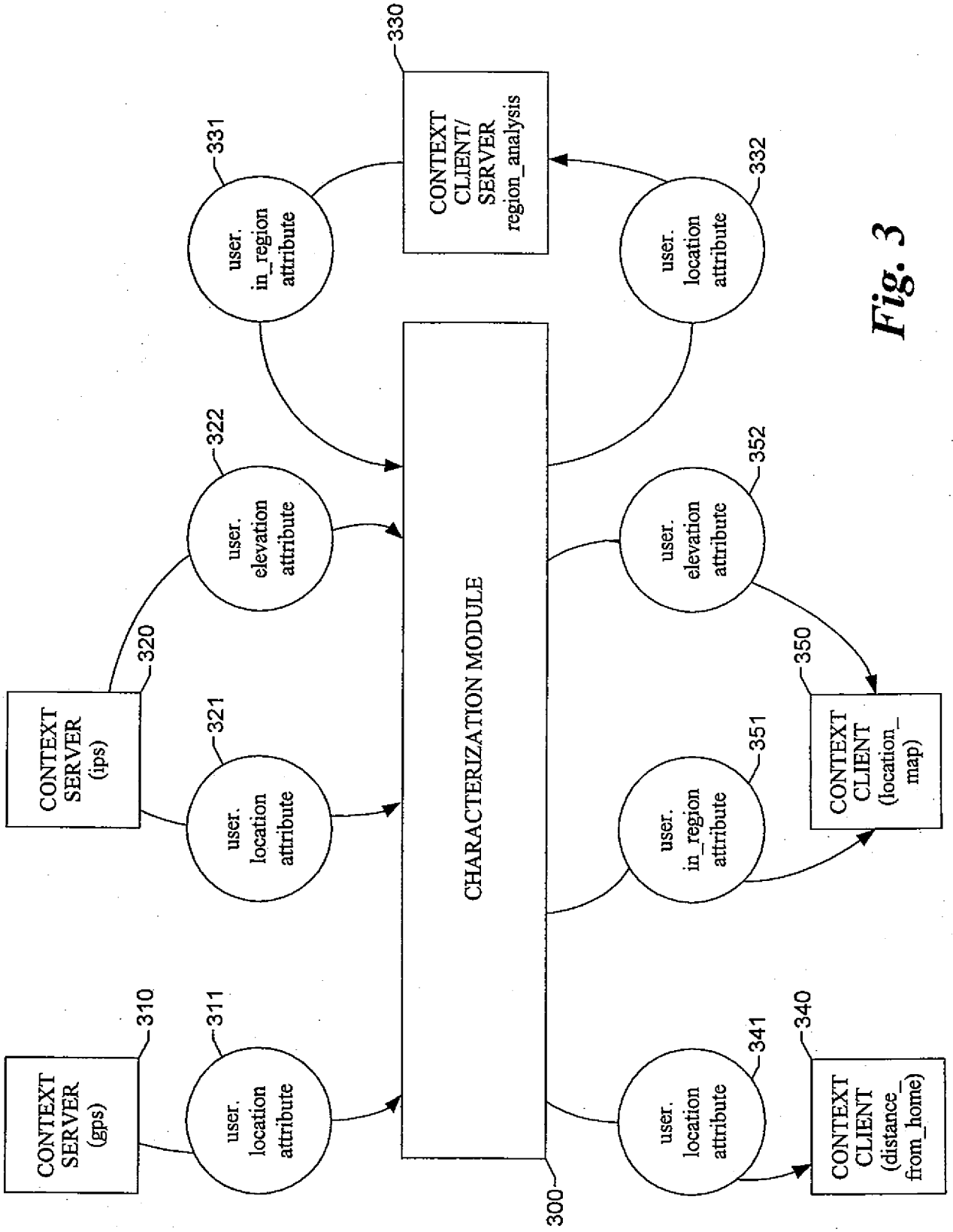

CONTEXT SERVER (gps)
310
user. location attribute
311
CONTEXT SERVER (ips)
320
user. elevation attribute
322
user. location attribute
321
CHARACTERIZATION MODULE
300
CONTEXT CLIENT/ SERVER region_analysis
330
user. in_region attribute
331
user. location attribute
332
user. elevation attribute
352
CONTEXT CLIENT (location_ map)
350
user. in_region attribute
351
user. location attribute
341
CONTEXT CLIENT (distance_ from_home)
340

Fig. 3

context server table 400

	context server name	version	installation date	filename	request handler
401	gps	1	2/10/2000	gps.exe	(reference)
402	ips	1	2/21/2000	ips.exe	(reference)
403	location_region_analysis	1	2/10/2000	l_r_a.exe	(reference)
	411	412	413	414	415

Fig. 4

500 attribute instance table

	attribute name	context server name	value	uncertainty	timestamp	units	number of context clients consuming
501	user.location	gps	47° 38.73' N, 122° 18.43' W	0° .09'	13:11:04.023 2/22/2000	degrees/minutes	2
502	user.location	ips	47° 38.745' N, 122° 18.424' W	0° .021'	13:11:01.118 2/22/2000	degrees/minutes	2
503	user.elevation	ips	22	.5	13:11:01.118 2/22/2000	meters	1
504	user.in_region	location_region_ analysis	none	none	none	none	0
	511	512	513	514	515	516	517

Fig. 5

600

context client table

context clent name	message handler
location_map	(reference)
distance_from_home	(reference)
region_analysis	(reference)

601 602 603

611 612

Fig. 6

700

attribute instance table

attribute name	context server name	value	uncertainty	timestamp	units	number of context clients consuming
user.location	gps	47° 38.73' N, 122° 18.43' W	0° .09'	13:11:04.023 2/22/2000	degrees/minutes	2
user.location	ips	47° 38.745' N, 122° 18.424' W	0° .021'	13:11:01.118 2/22/2000	degrees/minutes	2
user.elevation	ips	22	.5	13:11:01.118 2/22/2000	meters	1
user.in_region	location_region_analysis	none	none	none	none	1

701 702 703 704

711 712 713 714 715 716 717

Fig. 7

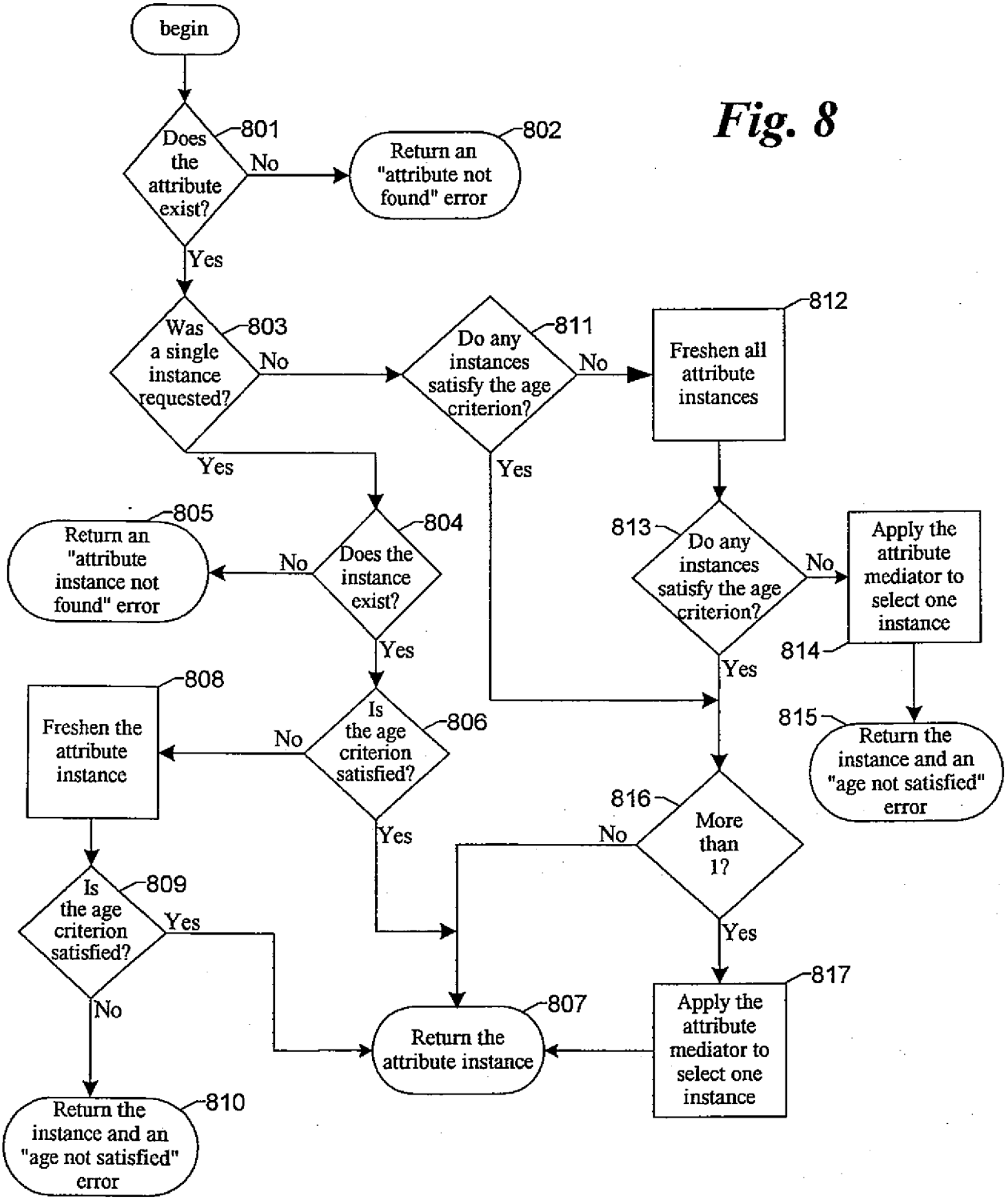

begin
Does the attribute exist?
801
No
Return an "attribute not found" error
802
Yes
Was a single instance requested?
803
No
Yes
Do any instances satisfy the age criterion?
811
No
Yes
Freshen all attribute instances
812
Does the instance exist?
804
No
Return an "attribute instance not found" error
805
Yes
Is the age criterion satisfied?
806
No
Freshen the attribute instance
808
Yes
Is the age criterion satisfied?
809
Yes
No
Return the instance and an "age not satisfied" error
810
Return the attribute instance
807
Do any instances satisfy the age criterion?
813
No
Apply the attribute mediator to select one instance
814
Yes
Return the instance and an "age not satisfied" error
815
More than 1?
816
No
Yes
Apply the attribute mediator to select one instance
817

Fig. 8

900

attribute instance table

	attribute name	context server name	value	uncertainty	timestamp	units	number of context clients consuming
901	user.location	gps	47° 38.73' N, 122° 18.43' W	0° .09'	13:11:04.023 2/22/2000	degrees/minutes	2
902	user.location	ips	47° 38.745' N, 122° 18.424' W	0° .021'	13:11:01.118 2/22/2000	degrees/minutes	2
903	user.elevation	ips	22.25	.5	13:11:06.565 2/22/2000	meters	1
904	user.in_region	region_analysis	none	none	none	none	1
	911	912	913	914	915	916	917

Fig. 9

1000

condition table

	condition name	context client name	first logical parameter	second logical parameter	comparison value	logical operator
1001	in_region_true	region_analysis	user.in_region	none	TRUE	=
	1011	1012	1013	1014	1015	1016

Fig. 10

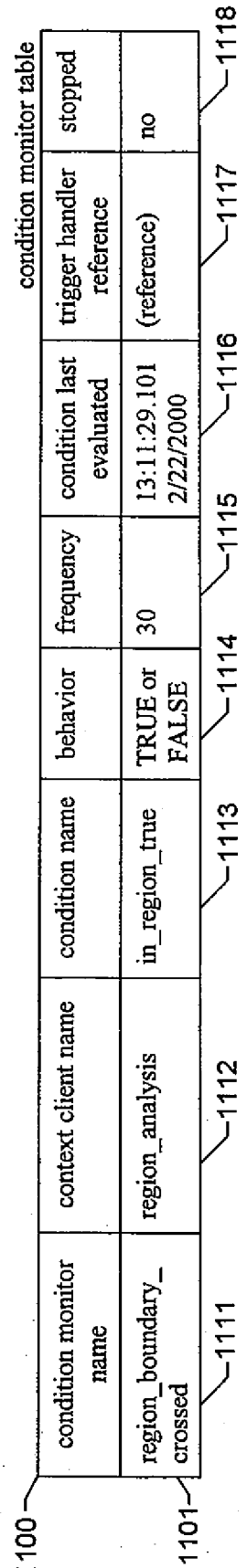

1100
condition monitor table
condition monitor name
context client name
condition name
behavior
frequency
condition last evaluated
trigger handler reference
stopped
region_boundary_crossed
region_analysis
in_region_true
TRUE or FALSE
30
13:11:29.101 2/22/2000
(reference)
no
1101
1111
1112
1113
1114
1115
1116
1117
1118

Fig. 11

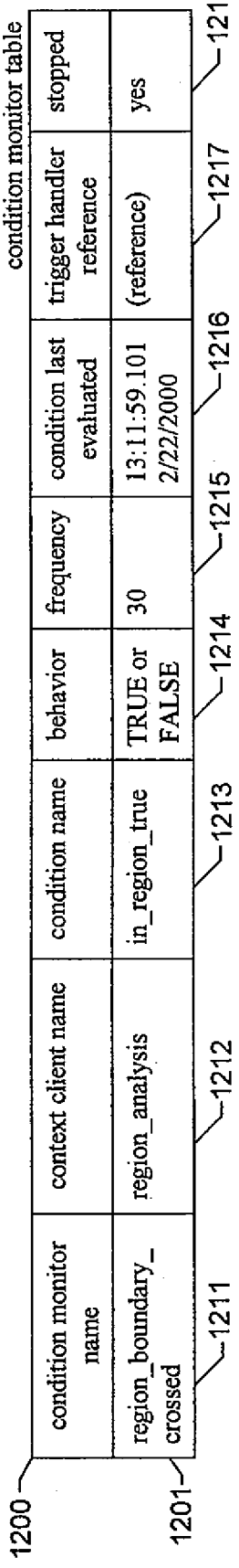

1200
condition monitor table
condition monitor name
context client name
condition name
behavior
frequency
condition last evaluated
trigger handler reference
stopped
region_boundary_crossed
region_analysis
in_region_true
TRUE or FALSE
30
13:11:59.101 2/22/2000
(reference)
yes
1201
1211
1212
1213
1214
1215
1216
1217
1218

Fig. 12

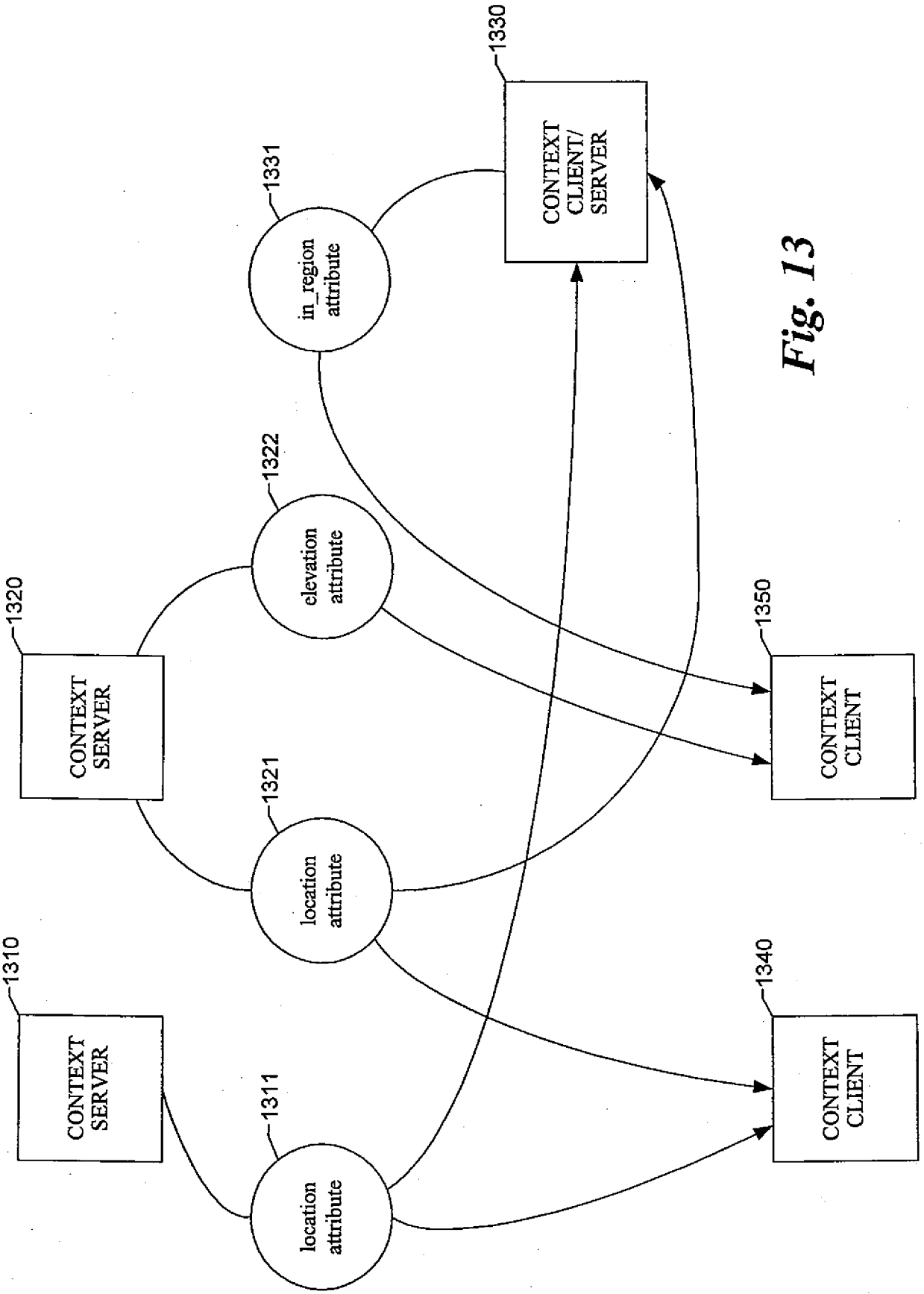

1330
CONTEXT CLIENT/ SERVER
1331
in_region attribute
1322
elevation attribute
1320
CONTEXT SERVER
1350
CONTEXT CLIENT
1321
location attribute
1310
CONTEXT SERVER
1340
CONTEXT CLIENT
1311
location attribute

Fig. 13

attribute request table

	attribute name	context client name
1401	user.location	distance_from_home
1402	user.in_region	location_map
1403	user.location [gps]	location_region_analysis
1404	user.elevation	location_map

1411 1412

Fig. 14

User.
- Desired_privacy_level
- Interruptibility
- Speed
- Direction
- Acceleration
- Availability.
  - Cognitive_availability
  - Tactile_availability
  - Manual_availability
  - Visual_availability
  - Oral_availability
  - Auditory_availability
- Proximity.<Item or place name>
- Mood.
  - Happiness
  - Sadness
  - Anger
  - Frustration
  - Confusion
- Activity.
  - Driving
  - Eating
  - Running
  - Sleeping
  - Talking
  - Typing
  - Walking
- Location.
  - Place_name
  - Latitude
  - Longitude
  - Altitude
  - Room
  - Floor
  - Building
  - Address
  - Street
  - City
  - County
  - State
  - Country
  - Postal_Code
- Destination. (same as User.Location.)
- Physiology.
  - Pulse
  - Body_temperature
  - Blood_pressure
  - Respiration

Person.<name or ID>. (same as User.)

Platform.
- UI.
  - Oral_input_device_availability
  - Manual_input_device_availability
  - Tactile_output_device_availability
  - Visual_output_device_availability
  - Auditory_output_device_availability

Platform. (continued)
- CPU.
  - Load
  - Speed
- Memory.
  - Total_capacity
  - Used
- Storage.
  - Total_capacity
  - Used
- Connectivity.
  - Connection_status
  - Connection_speed
  - Connection_type/device
  - Connection_activity
- Power.
  - Power_source
  - Power_level

Environment.
- People.
  - Nearest
  - Number_present
  - Number_close
- Local.
  - Time
  - Date
  - Temperature
  - Pressure
  - Wind_speed
  - Wind_direction
  - Absolute_humidity
  - High_forecast_temperature
  - Low_forecast_temperature
  - People_present
  - Ambient_noise_level
  - Ambient_light_level
  - Days.<previous or future>.
    - High_temperature
    - Low_temperature
    - Precipitation_type
    - Precipitation_amount
- Place.<place name>. (same as Environment.Local)

Application.
- Mail.
  - Available
  - New_messages_waiting
  - Messages_waiting_to_be_sent
- Phone.
  - Available
  - In_use
  - On/off
  - Notification_mechanism
  - Call_incoming
  - Caller_ID
- Sound_recorder.
  - Available
  - Recording

Fig. 15

Fig. 16

1) User Setting
   a) Mental Context
      i) Meaning
      ii) Cognition
         (1) Divided User Attention
         (2) Task Switching
         (3) Background Awareness
      iii) Solitude
      iv) Privacy
         (1) Desired Privacy
         (2) Perceived Privacy
      v) Social Context
      vi) Affect
   b) Physical Situation
      i) Body
         (1) Biometrics
         (2) Posture
         (3) Motion
         (4) Physical Encumberment
            (a) Senses
               (i) Eyes
               (ii) Ears
               (iii) Tactile
               (iv) Hands
               (v) Nose
               (vi) Tongue
            (b) Workload demands/effects
            (c) Interaction with computer devices
            (d) Interaction with people
            (e) Physical Health
      ii) Environment
         (1) Time/Space
         (2) Objects
         (3) Persons
            (a) Audience/Privacy Availability
               (i) Scope of Disclosure
               (ii) Hardware affinity for privacy
               (iii) Privacy Indicator for User
               (iv) Privacy Indicator for Public
               (v) Watching Indicator
               (vi) Being Observed Indicator
         (4) Ambient Interference
            (a) Visual
            (b) Audio
            (c) Tactile

2) Computer
   a) Power
   b) Configuration
      i) User Input Systems
         (1) Hand/Haptic
            (a) Keyboard/Keystrokes
         (2) Voice/Audio
         (3) Eye Tracking
         (4) Cursors
            (a) Axis
            (b) Resolution
               (i) Selection
               (ii) Invocation
            (c) Accelerators
      ii) Output Systems
         (1) Visual
            (a) Resolution
         (2) Audio
            (a) Public/Private
         (3) Haptic
      iii) External Resources
         (1) I/O devices
         (2) Connectivity
   c) Data
      i) Quantity/State
      ii) Urgency/Importance
         (1) Use of Prominence
      iii) Modality
      iv) Sensitivity/Purpose
         (1) Privacy Issues
         (2) Use of Association
         (3) Use of Safety
      v) Source/Ownership
         (1) Types
            (a) User generated
            (b) Other computers or people
            (c) Sensor
            (d) PC State
         (2) Use of Association

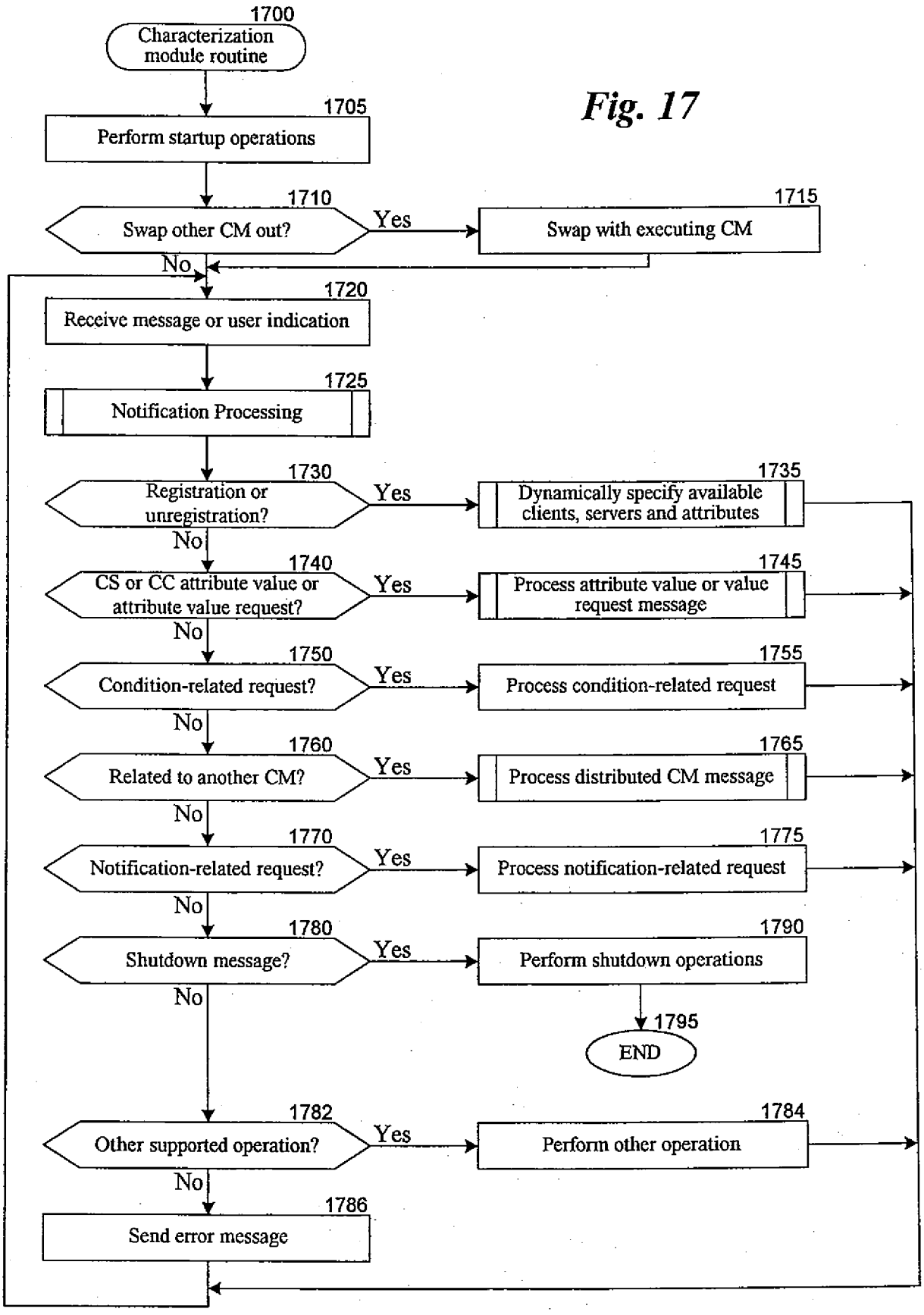
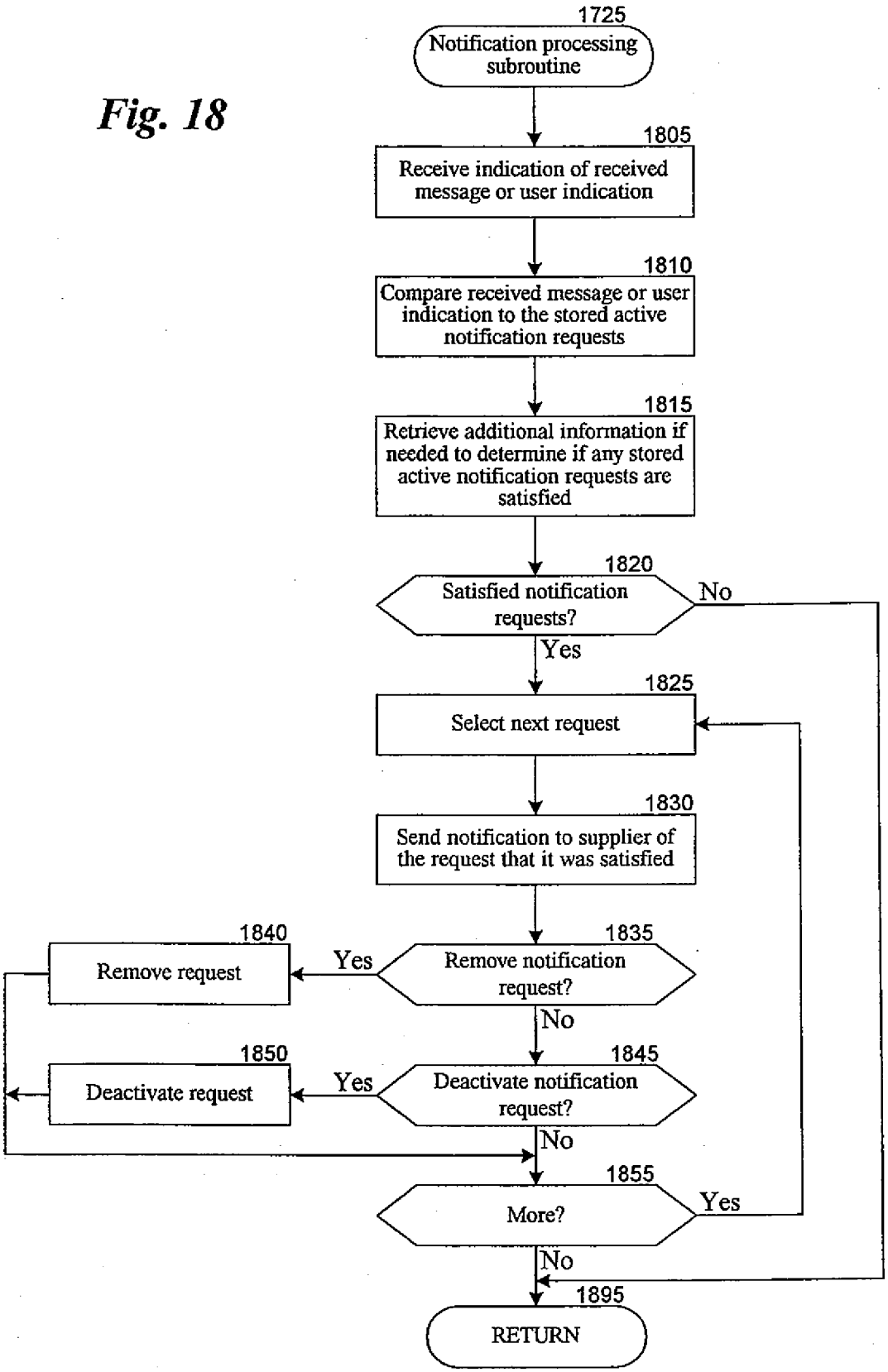

1700
Characterization module routine
1705
Perform startup operations
1710
Swap other CM out?
Yes
1715
Swap with executing CM
No
1720
Receive message or user indication
1725
Notification Processing
1730
Registration or unregistration?
Yes
1735
Dynamically specify available clients, servers and attributes
No
1740
CS or CC attribute value or attribute value request?
Yes
1745
Process attribute value or value request message
No
1750
Condition-related request?
Yes
1755
Process condition-related request
No
1760
Related to another CM?
Yes
1765
Process distributed CM message
No
1770
Notification-related request?
Yes
1775
Process notification-related request
No
1780
Shutdown message?
Yes
1790
Perform shutdown operations
No
1795
END
1782
Other supported operation?
Yes
1784
Perform other operation
No
1786
Send error message

Fig. 17

Fig. 18


1725
Notification processing subroutine
1805
Receive indication of received message or user indication
1810
Compare received message or user indication to the stored active notification requests
1815
Retrieve additional information if needed to determine if any stored active notification requests are satisfied
1820
Satisfied notification requests?
No
Yes
1825
Select next request
1830
Send notification to supplier of the request that it was satisfied
1835
Remove notification request?
Yes
1840
Remove request
No
1845
Deactivate notification request?
Yes
1850
Deactivate request
No
1855
More?
Yes
No
1895
RETURN

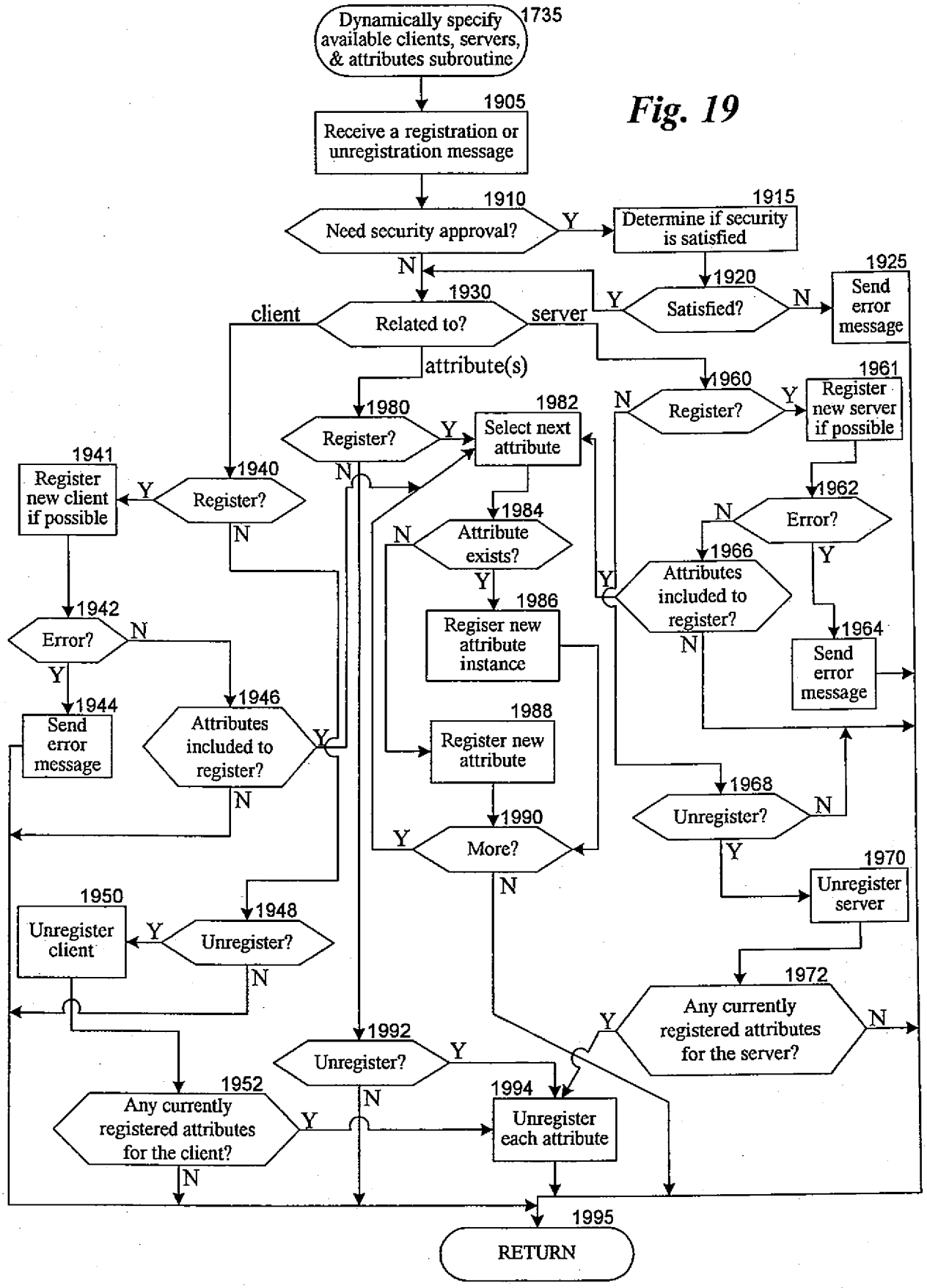

Dynamically specify available clients, servers, & attributes subroutine
1735
1905
Receive a registration or unregistration message
1910
Need security approval?
Y
1915
Determine if security is satisfied
N
1920
Satisfied?
N
1925
Send error message
Y
1930
client
Related to?
server
attribute(s)
1960
Register?
N
Y
1961
Register new server if possible
1962
Error?
N
Y
1964
Send error message
1966
Attributes included to register?
N
Y
1968
Unregister?
N
Y
1970
Unregister server
1972
Any currently registered attributes for the server?
Y
N
1980
Register?
Y
N
1982
Select next attribute
1984
Attribute exists?
N
Y
1986
Regiser new attribute instance
1988
Register new attribute
1990
More?
Y
N
1940
Register?
Y
N
1941
Register new client if possible
1942
Error?
N
Y
1944
Send error message
1946
Attributes included to register?
Y
N
1948
Unregister?
Y
N
1950
Unregister client
1992
Unregister?
Y
N
1994
Unregister each attribute
1952
Any currently registered attributes for the client?
Y
N
1995
RETURN

Fig. 19

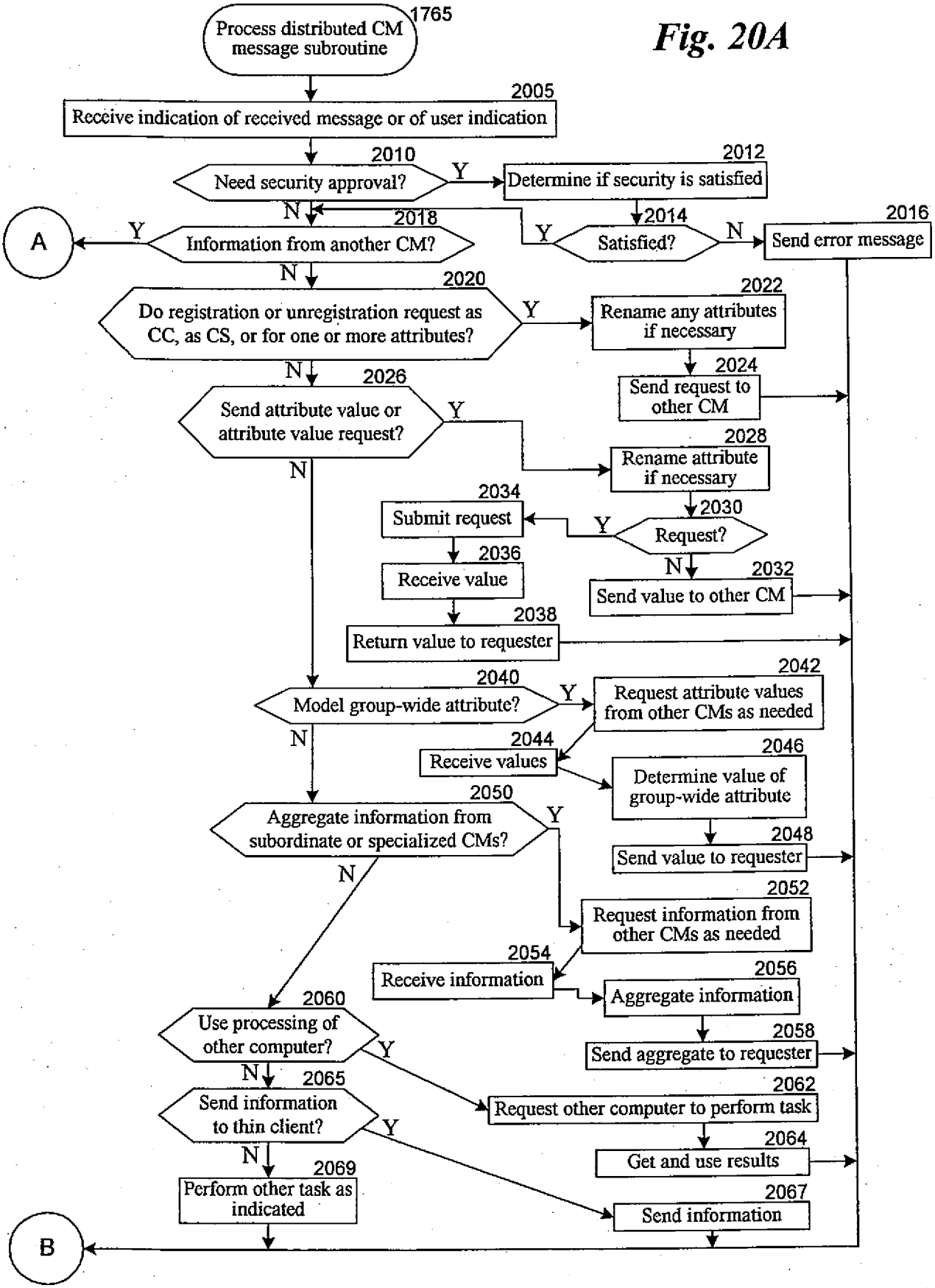

Process distributed CM message subroutine
1765
2005
Receive indication of received message or of user indication
2010
Need security approval?
Y
2012
Determine if security is satisfied
N
2018
Information from another CM?
Y
A
N
2014
Satisfied?
Y
N
2016
Send error message
2020
Do registration or unregistration request as CC, as CS, or for one or more attributes?
Y
2022
Rename any attributes if necessary
N
2024
Send request to other CM
2026
Send attribute value or attribute value request?
Y
2028
Rename attribute if necessary
N
2034
Submit request
Y
2030
Request?
2036
Receive value
N
2032
Send value to other CM
2038
Return value to requester
2040
Model group-wide attribute?
Y
2042
Request attribute values from other CMs as needed
N
2044
Receive values
2046
Determine value of group-wide attribute
2050
Aggregate information from subordinate or specialized CMs?
Y
2048
Send value to requester
N
2052
Request information from other CMs as needed
2054
Receive information
2056
Aggregate information
2060
Use processing of other computer?
Y
2058
Send aggregate to requester
N
2065
Send information to thin client?
2062
Request other computer to perform task
Y
2064
Get and use results
N
2069
Perform other task as indicated
2067
Send information
B

Fig. 20A

Fig. 20B

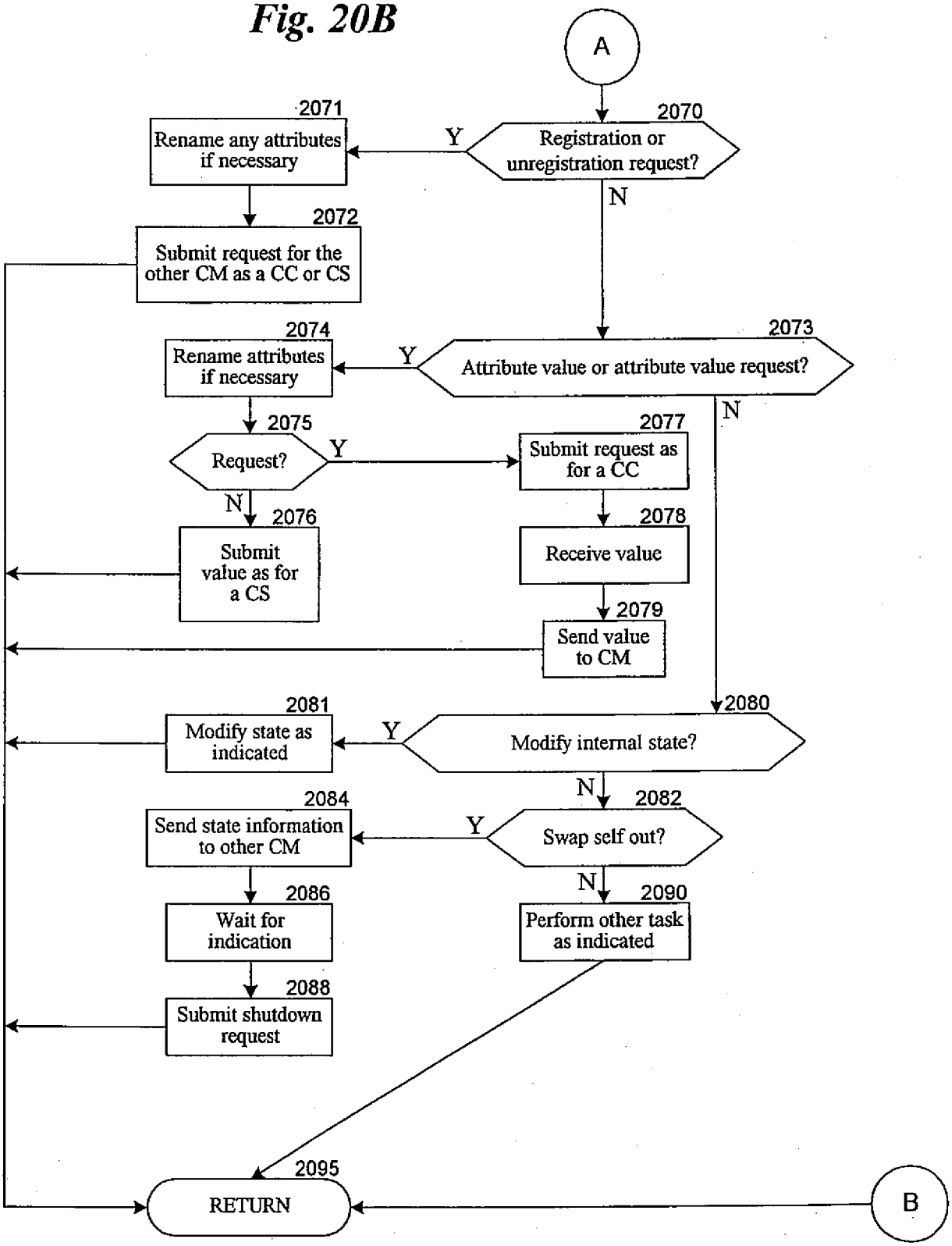
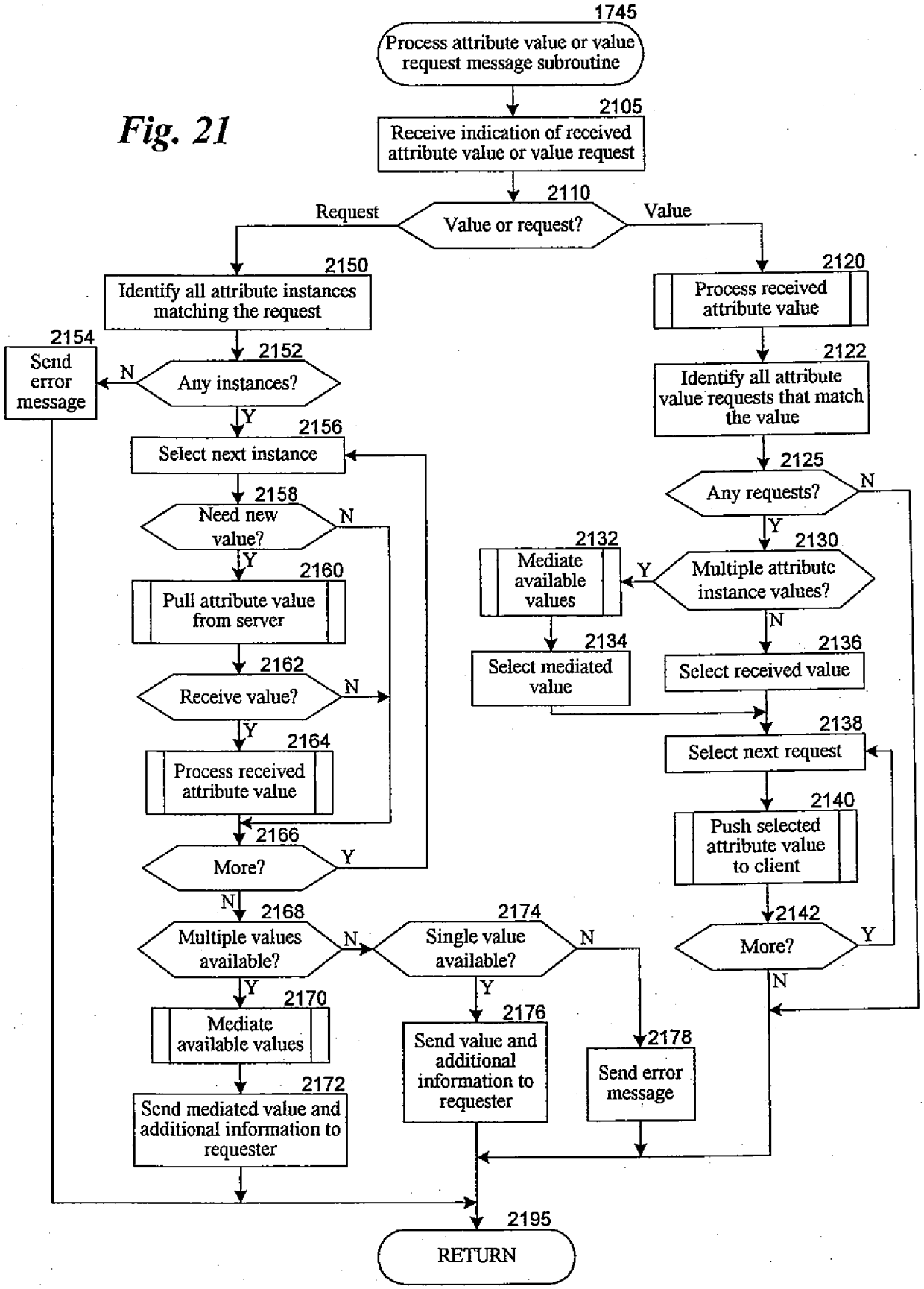

A
2070
Registration or unregistration request?
Y
2071
Rename any attributes if necessary
N
2072
Submit request for the other CM as a CC or CS
2073
Attribute value or attribute value request?
Y
2074
Rename attributes if necessary
N
2075
Request?
Y
2077
Submit request as for a CC
N
2076
Submit value as for a CS
2078
Receive value
2079
Send value to CM
2080
Modify internal state?
Y
2081
Modify state as indicated
N
2082
Swap self out?
Y
2084
Send state information to other CM
N
2090
Perform other task as indicated
2086
Wait for indication
2088
Submit shutdown request
2095
RETURN
B

Fig. 21


1745
Process attribute value or value request message subroutine
2105
Receive indication of received attribute value or value request
2110
Value or request?
Request
Value
2150
Identify all attribute instances matching the request
2154
Send error message
2152
Any instances?
N
Y
2156
Select next instance
2158
Need new value?
N
Y
2160
Pull attribute value from server
2162
Receive value?
N
Y
2164
Process received attribute value
2166
More?
Y
N
2168
Multiple values available?
N
Y
2170
Mediate available values
2172
Send mediated value and additional information to requester
2174
Single value available?
N
Y
2176
Send value and additional information to requester
2178
Send error message
2120
Process received attribute value
2122
Identify all attribute value requests that match the value
2125
Any requests?
N
Y
2130
Multiple attribute instance values?
Y
N
2132
Mediate available values
2134
Select mediated value
2136
Select received value
2138
Select next request
2140
Push selected attribute value to client
2142
More?
Y
N
2195
RETURN

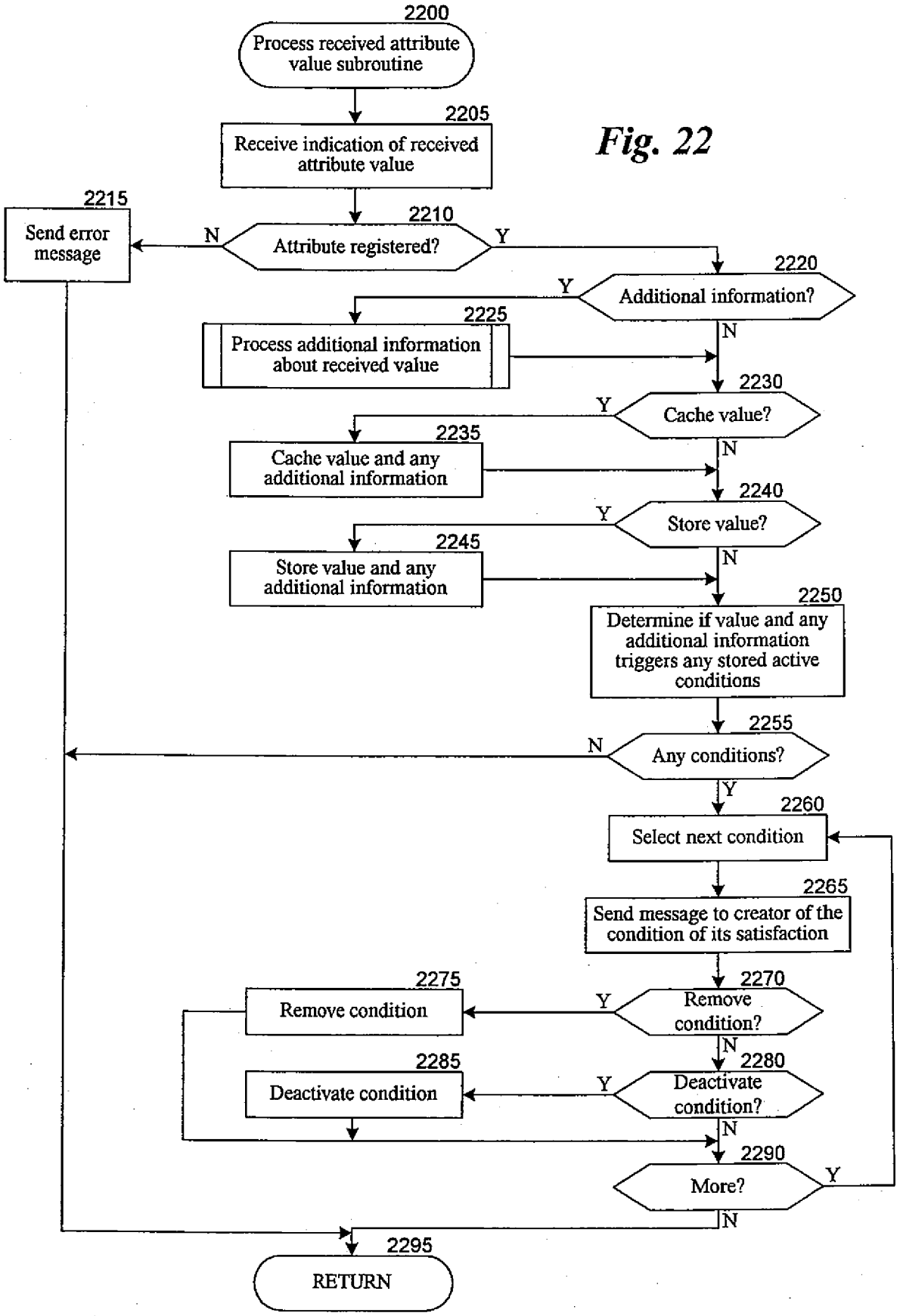

2200
Process received attribute value subroutine
2205
Receive indication of received attribute value
2210
Attribute registered?
N
2215
Send error message
Y
2220
Additional information?
Y
2225
Process additional information about received value
N
2230
Cache value?
Y
2235
Cache value and any additional information
N
2240
Store value?
Y
2245
Store value and any additional information
N
2250
Determine if value and any additional information triggers any stored active conditions
2255
Any conditions?
N
Y
2260
Select next condition
2265
Send message to creator of the condition of its satisfaction
2270
Remove condition?
Y
2275
Remove condition
N
2280
Deactivate condition?
Y
2285
Deactivate condition
N
2290
More?
Y
N
2295
RETURN

Fig. 22

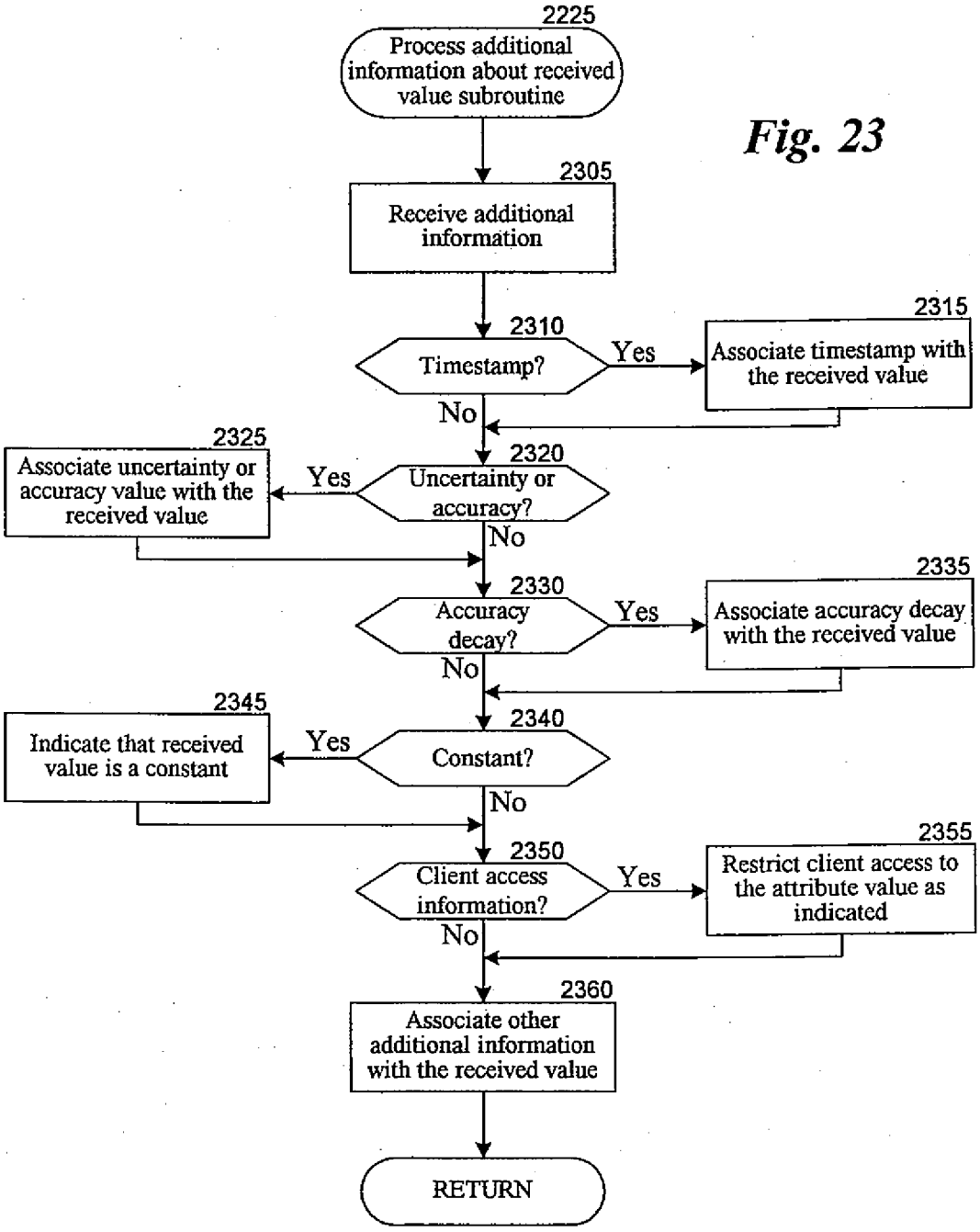

2225
Process additional information about received value subroutine
2305
Receive additional information
2310
Timestamp?
Yes
2315
Associate timestamp with the received value
No
2320
Uncertainty or accuracy?
Yes
2325
Associate uncertainty or accuracy value with the received value
No
2330
Accuracy decay?
Yes
2335
Associate accuracy decay with the received value
No
2340
Constant?
Yes
2345
Indicate that received value is a constant
No
2350
Client access information?
Yes
2355
Restrict client access to the attribute value as indicated
No
2360
Associate other additional information with the received value
RETURN

Fig. 23

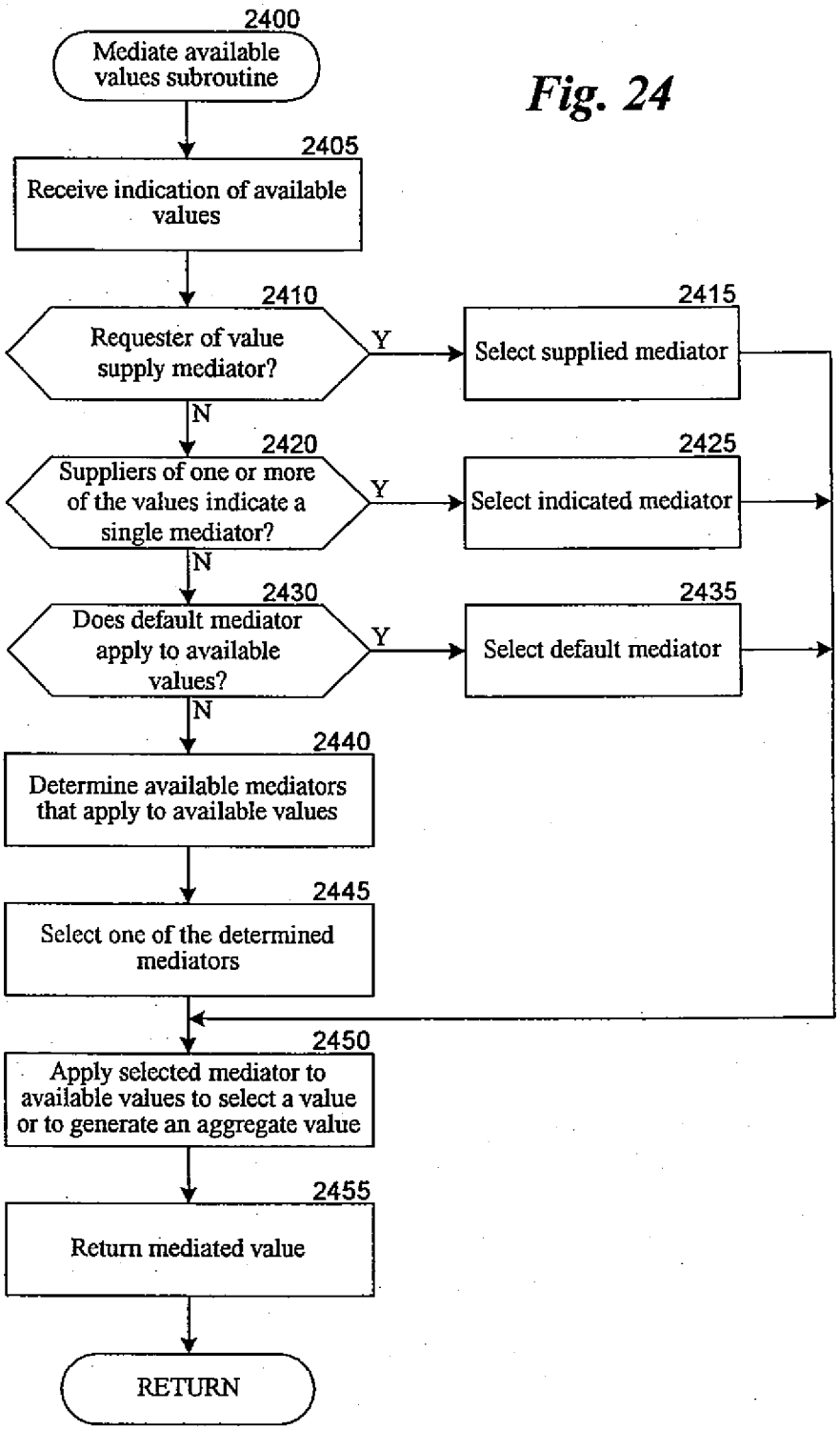

2400
Mediate available values subroutine
2405
Receive indication of available values
2410
Requester of value supply mediator?
Y
2415
Select supplied mediator
N
2420
Suppliers of one or more of the values indicate a single mediator?
Y
2425
Select indicated mediator
N
2430
Does default mediator apply to available values?
Y
2435
Select default mediator
N
2440
Determine available mediators that apply to available values
2445
Select one of the determined mediators
2450
Apply selected mediator to available values to select a value or to generate an aggregate value
2455
Return mediated value
RETURN

Fig. 24

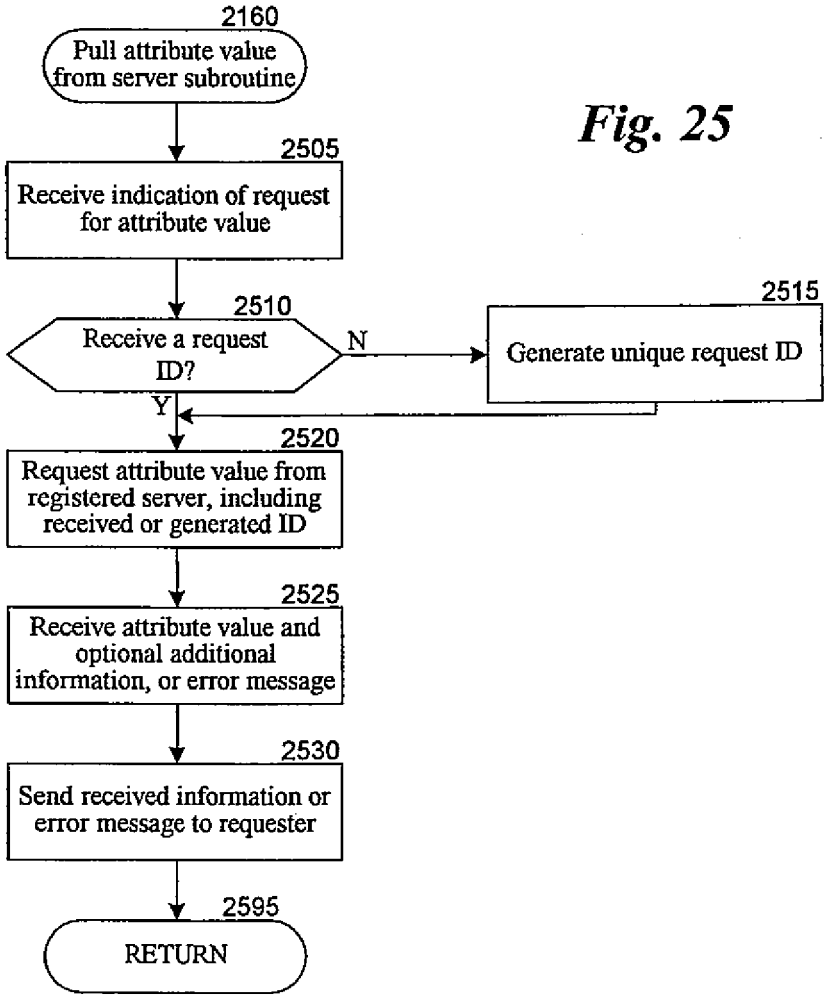

2160
Pull attribute value from server subroutine
2505
Receive indication of request for attribute value
2510
Receive a request ID?
N
2515
Generate unique request ID
Y
2520
Request attribute value from registered server, including received or generated ID
2525
Receive attribute value and optional additional information, or error message
2530
Send received information or error message to requester
2595
RETURN

Fig. 25

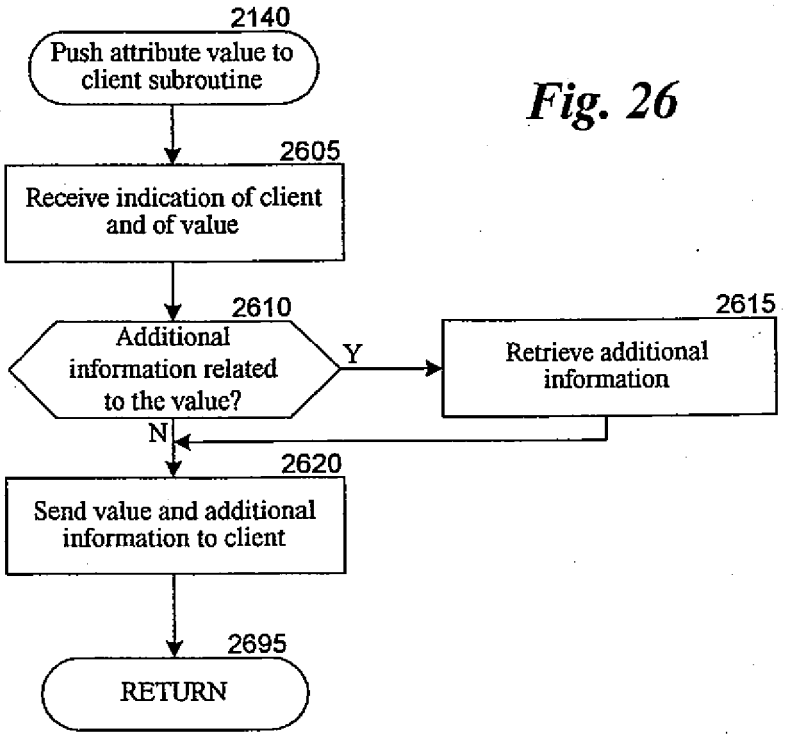

2140
Push attribute value to client subroutine
2605
Receive indication of client and of value
2610
Additional information related to the value?
Y
2615
Retrieve additional information
N
2620
Send value and additional information to client
2695
RETURN

Fig. 26

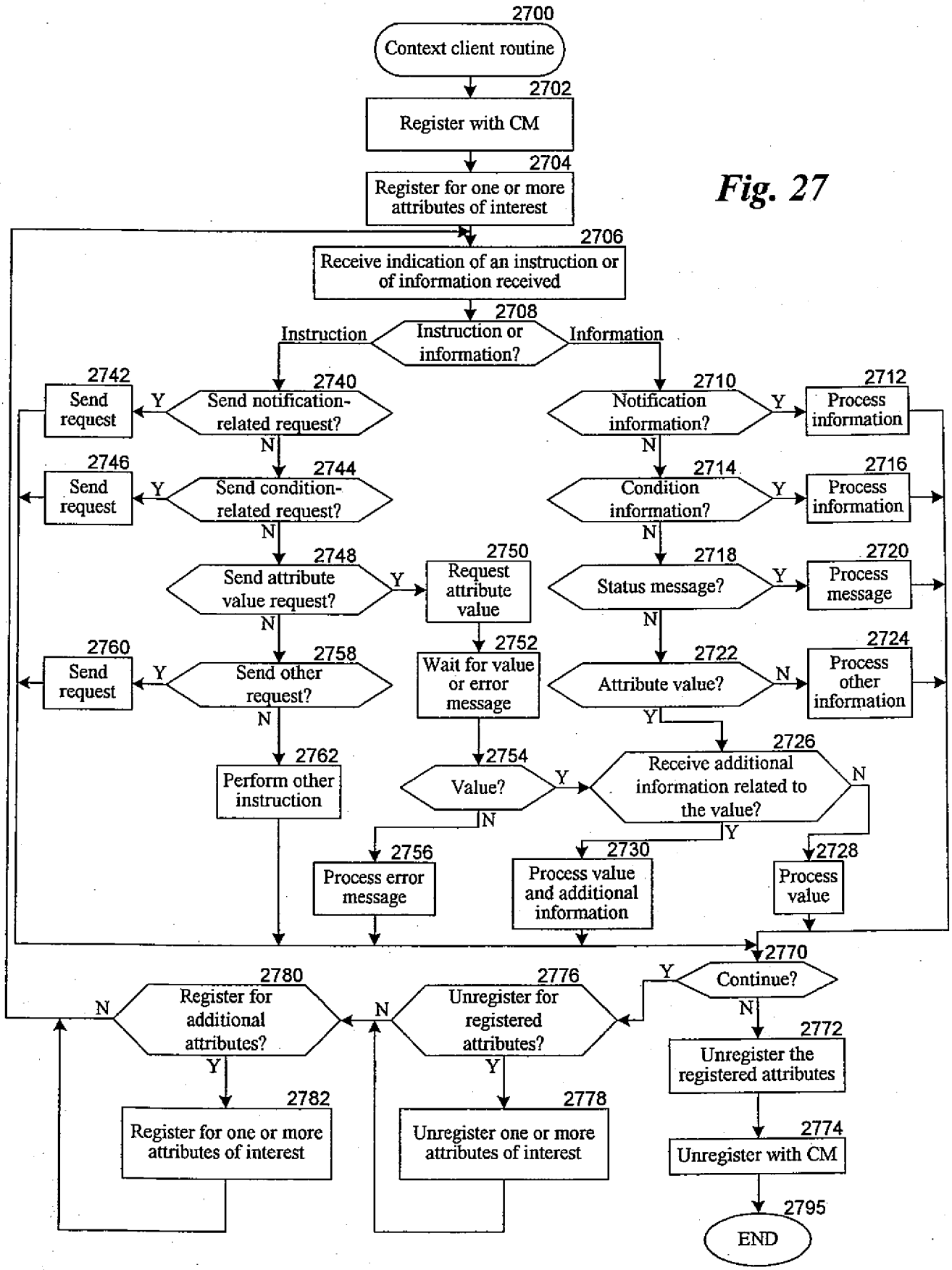

2700
Context client routine
2702
Register with CM
2704
Register for one or more attributes of interest
2706
Receive indication of an instruction or of information received
2708
Instruction or information?
Instruction
Information
2742
Send request
Y
2740
Send notification-related request?
N
2746
Send request
Y
2744
Send condition-related request?
N
2748
Send attribute value request?
Y
2750
Request attribute value
N
2760
Send request
Y
2758
Send other request?
N
2762
Perform other instruction
2752
Wait for value or error message
2754
Value?
Y
N
2756
Process error message
2710
Notification information?
Y
2712
Process information
N
2714
Condition information?
Y
2716
Process information
N
2718
Status message?
Y
2720
Process message
N
2722
Attribute value?
N
2724
Process other information
Y
2726
Receive additional information related to the value?
N
Y
2730
Process value and additional information
2728
Process value
2770
Continue?
Y
N
2772
Unregister the registered attributes
2774
Unregister with CM
2795
END
2776
Unregister for registered attributes?
N
Y
2778
Unregister one or more attributes of interest
2780
Register for additional attributes?
N
Y
2782
Register for one or more attributes of interest

Fig. 27

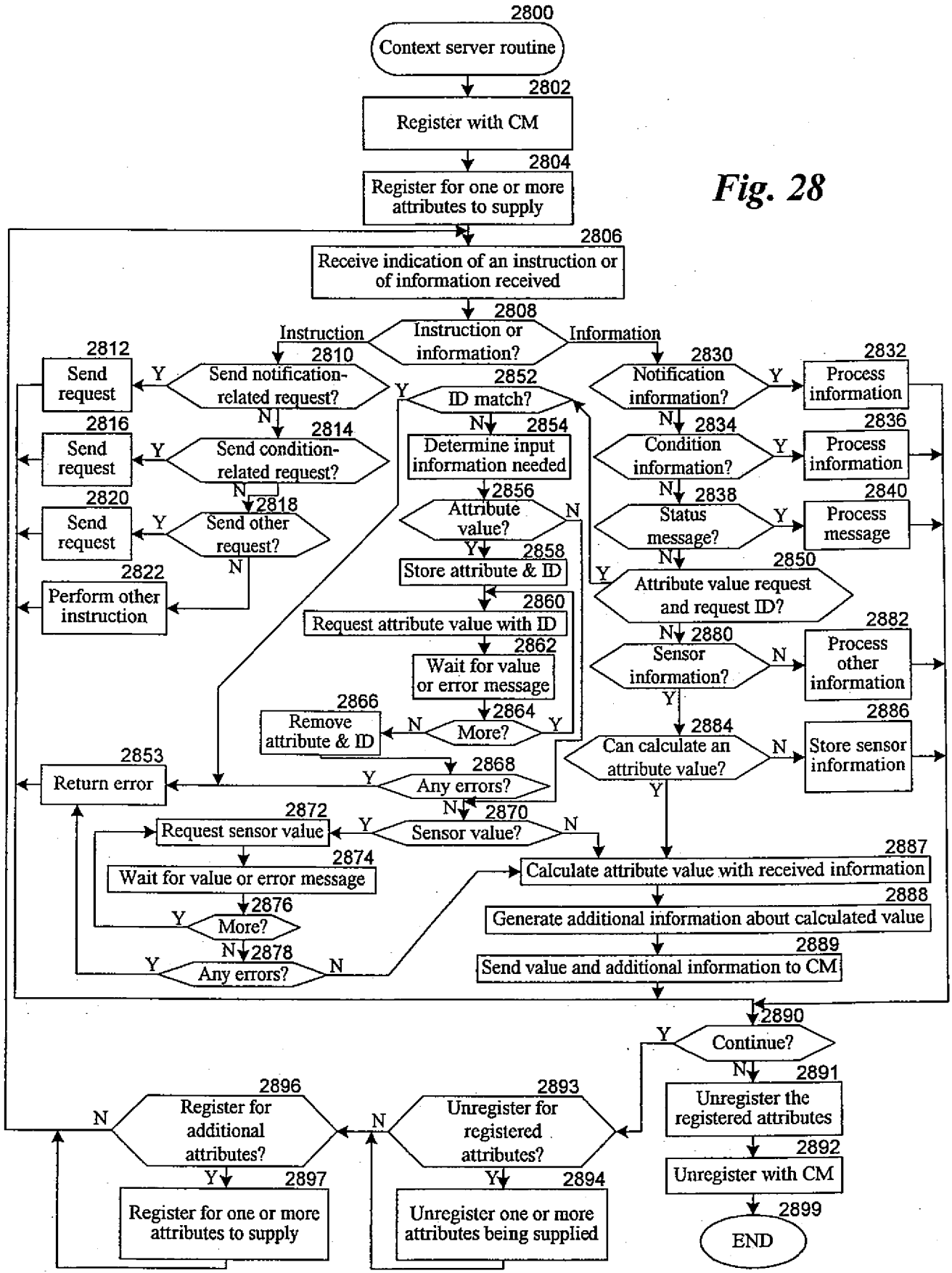

2800
Context server routine
2802
Register with CM
2804
Register for one or more attributes to supply
2806
Receive indication of an instruction or of information received
2808
Instruction or information?
Instruction
Information
2810
Send notification-related request?
2812
Send request
2814
Send condition-related request?
2816
Send request
2818
Send other request?
2820
Send request
2822
Perform other instruction
2852
ID match?
2854
Determine input information needed
2856
Attribute value?
2858
Store attribute & ID
2860
Request attribute value with ID
2862
Wait for value or error message
2864
More?
2866
Remove attribute & ID
2853
Return error
2868
Any errors?
2870
Sensor value?
2872
Request sensor value
2874
Wait for value or error message
2876
More?
2878
Any errors?
2830
Notification information?
2832
Process information
2834
Condition information?
2836
Process information
2838
Status message?
2840
Process message
2850
Attribute value request and request ID?
2880
Sensor information?
2882
Process other information
2884
Can calculate an attribute value?
2886
Store sensor information
2887
Calculate attribute value with received information
2888
Generate additional information about calculated value
2889
Send value and additional information to CM
2890
Continue?
2891
Unregister the registered attributes
2892
Unregister with CM
2899
END
2893
Unregister for registered attributes?
2894
Unregister one or more attributes being supplied
2896
Register for additional attributes?
2897
Register for one or more attributes to supply
Y
N

Fig. 28